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OVERVIEW

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Resocializing digital water transformations: Outlining social science perspectives on the digital water journey

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Abstract

Digital water transformation is often written about as though universally desirable and inevitable, capable of addressing the multifaceted socioecological challenges that water systems face. However, there is not widespread reflection on the complexities, tensions and unintended consequences of digital transformation, its social and political dimensions are often neglected. This article introduces case studies of digital water development, bringing examples of technological innovation into dialogue with literature and empirical research from across the social sciences. We examine how Big Data affects our observations of water in society to shape water management, how the Internet of Things becomes involved in reproducing unjust water politics, how digital platforms are entangled in the varied sociocultural landscape of everyday water use, and how opensource technologies provide new possibilities for participatory water governance. We also reflect on regulatory developments and the possible trajectories of innovation resulting from public-private sector interactions. A socially and politically informed view of digital water is essential for just and sustainable development, and the gap between industry visions of digital water and research within the social sciences is inhibitive. Thus, the analysis presented in this article provides a novel, pluralistic perspective on digital water development and outlines what is required for more inclusive future scholarship, policy and practice.

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1 | INTRODUCTION

> There is no question that the digital age has arrived. Digital technologies are now embedded in our daily lives transforming sectors such as communications, transportation, entertainment, education, manufacturing and healthcare. The transformation is inevitable as water and wastewater utilities are now facing new risks from increasing demand, water scarcity, water quality and water security, exacerbated by aging and underfunded infrastructure, out of date public policies and climate change. The adoption of digital technologies will become increasingly necessary to provide improved, more reliable, secure, efficient, and cost-effective water and wastewater services. (Sarni, White, Webb, Cross, & Glotzbach, 2019, p. 34)

The International Water Association's *Digital Water* White Paper (Sarni et al., 2019) illustrates that digital technologies are becoming a central feature of water governance. Promised to transform relationships between water and society, digital technologies are seen to enable utilities to become "resilient, innovative, and efficient" by building "a stronger and more economically viable foundation for the future" (Sarni et al., 2019, p. 8). Sarni et al.'s (2019) view is by no means exceptional. For many, digital transformation is an inevitable progression within global water services, an integration of information and communication technologies within the sociotechnical infrastructure of water systems that can address the complex challenges that water systems face (Krause et al., 2018). Though technologically progressive, these visions rarely reflect on the social and political implications of digital transformation. Important questions regarding how digital transformations reproduce and reconfigure water governance are not typically considered and the socioecological injustices that digital developments may disrupt or maintain remain unacknowledged.

To counter these techno-centric visions, this article synthesizes insights from an interdisciplinary body of social science literature. Digital developments are positioned as sociotechnical interventions that transform water politics at different scales. These discussions are situated in a hydrosocial tradition, a sociogeographical perspective that attends to the social and political nature of water to aid critical reflection on developments in water systems (Linton & Budds, 2014). One of the key developments of the hydrosocial literature is to reveal how "modern water," a representation that abstracts water from its local social, political and historical conditions, has shaped much of 20th century water management (Linton, 2014). The logics of modern water are baked in to centralized water infrastructure and technocratic modes of management (Bakker, 2003; Sofoulis, 2005). Yet, the fundamental assumptions of modern water, which render water management asocial and apolitical are no longer commonly accepted. In various fields, a new hydrosocial contract is called for, one that reinfuses water management with social and political sensitivities to transform the trajectory of water systems and improve social and ecological outcomes (Brown, Rogers, & Werbeloff, 2018). This development has not yet permeated through visions of digital transformation and so our purpose is to further this dialogue.

Before proceeding it is useful to characterize digital transformation. The building blocks of digital transformation are concepts such as Big Data, the Internet of Things (IoT) and Smart Cities, and the computational artifacts and processes that enable them to function (Bakker & Ritts, 2018). Many analysts have sought to imagine the deployment of such technologies in the water sector (e.g., Allawi, Jaafar, Hamzah, & El-shafie, 2019; Lin, Petway, Lien, & Settele, 2018). For example, the use of remote sensing and enhanced visualization techniques can improve monitoring and prediction of water flows (Demirel et al., 2018), and the application of machine learning and artificial intelligence enable understanding of complex events, such as water-related conflicts (Kuzma et al., 2020). Other opportunities include the use of augmented and virtual reality technologies to simulate underground infrastructures for training and maintenance purposes (Kirby, Rozycki, Borthwick, & McKinnon, 2018), and the prospect of using blockchain and cryptocurrencies to increase the security and transparency of water-related transactions (Poberezhna, 2018).

There is no commonly accepted definition of digital transformation. In some instances, definitions center on organizational practices and technological innovation. For example, ElMassah and Mohieldin accentuate "the profound transformation of business and organizational activities, processes, competencies and models to fully leverage the changes and opportunities of a mix of digital technologies" (i-SCOOP.eu, 2016 in ElMassah & Mohieldin, 2020, p. 2). Digital transformations can also be understood in terms of their outcomes for society: "a process by which social existence is increasingly affected by digital processes, digital tools, and abundance of information" (Ossewaarde, 2019, p. 24). We propose that these definitions are not at odds, but accentuate different aspects of digital transformation; the mechanisms through which transformations occur, and the outcomes by which their social, political, and ecological implications can be observed.

Speculation on the possible impacts of digital transformation has highlighted many potential benefits for water systems, including extending the life of assets, reducing leaks and improving the quality and reliability of water supplies (De Stefano, 2019). Digital developments enhance predicative capacity, aiding the mitigation of social and environmental problems caused by water shortages, pollution, and floods (Krause et al., 2018; Sarni et al., 2019). Further, Big Data systems improve the modeling of complex water systems and reduce model uncertainties, enabling more informed risk management decisions (Shafiee, Barker, & Rasekh, 2018). Digital advances are seen to have particular potential in emerging economies where they enable "leapfrogging" of centralized water management to develop digitally-managed decentralized water systems (Vairavamoorthy & Sarni, 2018).

With such ambitious visions, it is unsurprising that the water sector is enthusiastic about digital transformation. However, we argue that there is need to reflect on the complexities, tensions and unintended consequences of digital transformation if they are to improve social and ecological outcomes. In order to attend to these issues, this article develops case studies of digital water developments, bringing examples of technological innovation into dialogue with theoretical and empirical research from across the social sciences. In doing so we highlight the relationships between digital transformation, water governance, social justice, knowledge systems, and water politics. Without consideration of the issues presented in this article, our concern is that digital water transformations will not address—and could further deepen—social and ecological problems. Instead, by further understanding these themes, there is the prospect of digital water transformation that is better able to provide a more just and sustainable future.

The article proceeds as follows: First, we explore Big Data and the digital gaze, examining how Big Data effects our observations of society, rendering some aspects of water visible and others obscure, with implications for water management. Second, we examine how digital water infrastructures and the Internet of Things become involved in reproducing spatial and social injustices in water service provision. Third, we explore how digital platforms become entangled in the varied sociocultural landscape of everyday water use, with implications for the inclusivity and efficacy of their implementation. Fourth, we reflect on digital regulation and expertise, considering how these shape digital transformation in the water sector. Fifth, we examine how digital technologies create possibilities for participation in water management, with potential to increase accountability and democratize decision making. Finally, the discussion explores what these insights mean for future scholarship, policy and practice, calling for more interdisciplinary, and participatory water governance.

2 | THE "DIGITAL GAZE": HOW BIG DATA AFFECTS KNOWLEDGE AND ACTION ON WATER

The wider availability and use of Big Data is one of the core features of digital transformation. Combined with algorithm development and machine learning techniques, Big Data promises to improve representation of complex relationships in water systems (Shafiee et al., 2018). Big Data refers to the rapid generation of high volumes of data, combining more data sources, and with greater variety and granularity than has previously been possible. The velocity of data acquisition compromises conventional analytical methods, and so Big Data is associated with enhanced processing techniques that enable effective analysis and visualization. Here we examine what is made visible through big data and their associated algorithms, and what remains invisible (Amoore & Piotukh, 2016).

Big Data promises to increase the responsiveness of water management and planning by enabling the visualization of actors, connections and relationships that were previously untraceable. Uncertainties are reduced, and otherwise intangible aspects of water systems are rendered observable, allowing, for example, modeling of the interactions between actors at different scales (Shafiee et al., 2018; Ward & Butler, 2016). Observations become more precise. For example, the moment a shower is turned on can be observed, as well as the duration that the shower flows, and its flow rate. And data from different sources more effectively combined, for example, smart meter data can be compared against weather, search history and sales data to better understand peak water demand (Parker & Wilby, 2013; Pullinger, Browne, Anderson, & Medd, 2013). In these ways, Big Data enables water companies to make sense of intricate patterns in water systems, and respond accordingly (Stewart et al., 2018).

Yet, Big Data does not necessarily ensure that water systems are more meaningfully represented, and can reaffirm assumptions that have so far inadequately characterized the dynamics of water systems. Positivist ideas are prevalent throughout water governance, and characteristic of modern water. In a positivist perspective, complex phenomena are described in functional terms. Water demand, for example, is expressed as the average volume of water demanded from a water body per person per unit of time (Sharp et al., 2011). In so far as positivist perspectives account for water use, it is typically portrayed as a function of consumers' rational decisions and the diffusion of domestic technologies (Browne, Pullinger, Medd, & Anderson, 2014; Michalec, Hayes, Longhurst, & Tudgey, 2019). However, such a characterization over simplifies the social, political and material contingencies of water use of water and disguises diversity (Sofoulis, 2011).

Though there is considerable research that advances a richer understanding of water systems, the logics of modern water continue in visions of digital water:

> Digital communication and engagement tools that deliver billing information, leak identification, remote valve control, resolution notifications, and water usage insight can make it easier for consumers to understand their water consumption habits, save money and protect their property from costly water damage. (Krause et al., 2018, p. 21)

In spite of advances in data acquisition and analysis, water demand continues to be interpreted as a function of individual behavior within a technologically deterministic domestic environment. Indeed, Hoolohan and Browne (2018) make the case that some of the principal data sources, such as microcomponent meters, simply expand existing assumptions rather than generating fundamentally different perspectives. Though pictures of water systems increase in resolution, they no additional insight into the multifaceted array of social and material elements that shape water management and use (Fam, Lahiri-Dutt, & Sofoulis, 2015; Kuijer, de Jong, & van Eijk, 2013).

By continuing to overlook important cultural, political and historical qualities of water system dynamics, Big Data risks sustaining a focus on technological innovation and consumer behavior, rather than supporting a more systemic approach to water management. For example, opportunities are missed to examine how societal standards of freshness or the material design of homes have changed over time and may continue to change in future (Browne, 2015). Nonlinear interactions between the water systems and, for example, gendered dimensions of domestic labor remain unrepresented (Watson, 2015). And Big Data techniques are yet to be thoroughly applied to reveal how the timing, frequency and duration of water use in the home relates to differences, for example, in household structure, life stage, (dis)ability, or employment (Browne, Pullinger, et al., 2014). These contingencies are well researched in the qualitative social sciences; however, quantitative analysis using Big Data is not yet common.

Similarly, prediction techniques continue to embed assumptions about the relationships between people and water that fail to address deep uncertainties faced in long-term investment and decision making. For example, even with Big Data future water demand continues to be characterized as a function of technology diffusion and population, which limits the capacity of models to present a more systemic view of how demand is produced and how it might change in future (Sharmina et al., 2019). Consequently, the many and varied roles that intermediaries (such as the fashion and beauty industry, or construction sector) play in shaping the trajectory of demand remain poorly represented. With the influence of these actors externalized, demand management remains the responsibility of water companies, customers and states (Browne, Medd, Pullinger, & Anderson, 2014).

There are important opportunities for big data to be used to improve representation of complex and nonlinear relationships, particularly by processing unstructured human-generated data (Shafiee et al., 2018). Unstructured human-generated data includes internet search data, documents, social media content (including text, audio video, and images) and maps. Algorithms, artificial intelligence and machine learning techniques can be used to make sense of these datasets and to identify relationships and patterns that were previously hidden. These are seeing increased uptake within the water sector, though traditional statistical methods are still more common and more complex social and political aspects of water systems continue to be under-represented (Sharmina et al., 2019). As big data analytics become established in the water sector it is important that we continue to question what properties of the water system they enable us to visualize, and what remains obscured.

A related concern is that while algorithms provide insight into complex sociotechnical systems, they can further obscure processes of data manipulation and inhibit critical reflection on the assumptions, understandings and framings of management practices (Crawford, 2016). Statistical models have a high degree of interpretability (the ability for someone to understand how predictions or inferences were made) due to their very nature in *characterizing* the relationship between variables. However, Kosek describes how algorithms "produce predictive ways of seeing that exceed their makers' capacities to know" (Kosek, 2017, p. 66). The proof of an algorithm's worth is assessed by its ability to predict, rather than its ability to perform a robust and verifiable procedure. This focus on maximizing predictive power shifts the focus away from interpretability (Chandler, 2019). As such, the accuracy of representation—and the reflexivity that might improve this accuracy or reduce accidental bias—is compromised. This issue is compounded by the fact that the technical capacity to develop algorithms are in the hands of a small, relatively homogenous, community of experts, and the inherent diversity within communities is not well represented (Criado Perez, 2019; Thylstrup & Veel, 2017).

Big Data continues a historical tradition of rendering water-related issues technical (Sofoulis, 2011). Questions regarding what is made visible or invisible through big data and their associated algorithms are pertinent because the type of data used by the water sector influences how water is managed. Data "frame new understandings, reinforce assumptions or experiences, decenter expectations, challenge dominant narratives, reveal phenomena, hide problems, and justify decisions" (Dourish & Gómez Cruz, 2018, p. 1). Presently, Big Data appear to further entrench modes of management that typify modern water and do little to unsettle or enhance some of the more problematic knowledge practices that arise within this paradigm. Algorithmic ways of thinking tend to construct hegemonic claims for digital knowledge (Machen & Nost, n.d.) in ways that marginalize water knowledges not readily represented in data form. There could be potential for Big Data to provide greater insight into the relational qualities of water use, and facilitate more systemic water management practices. However, we should not take these outcomes for granted and further dialogue between data sciences and social sciences should aim to further understanding how Big Data can be used to more fully represent water systems.

3 | DIGITAL WATER POLITICS AND THE INTERNET OF THINGS: THE CHANGING LANDSCAPE OF WATER INFRASTRUCTURE

Digital infrastructures and technologies can also be seen to perform political work with important consequences for water governance. The proliferation of digital technologies throughout the water system is transforming the way the water industry creates and captures value (Amankwaa, Asaaga, Fischer, & Awotwe, 2020; Owen, 2018). Empirical research highlights the implications of these changes for social justice and access to water services (McLean, 2020; Millington & Scheba, 2020; Truelove, 2019). One lens through which to examine these political dynamics is the integration of prepaid technologies (Water ATM and meters) with other "Internet of Things" (IoT) technologies in the Global South.

Prepaid technologies are well established and have seen large-scale deployment, notably in Africa and Asia where they are intended to ensure water services for off-grid and low-income communities, while avoiding the costs associated with late/nonpayment (Harvey, 2005; Schmidt, 2020; von Schnitzler, 2008). Recently, the introduction of IoT and smart applications in water systems have introduced new prepayment models, to make revenue while also enabling water providers to monitor and control consumption (Chambers & Evans, 2020). Water ATMs are increasingly smartcard operated, so that they not only provide a decentralized water supply infrastructure but also allow operators and water managers to observe consumption and increase accountability. In addition to traditional prepaid water meters that allow water-use up to the loaded limit, there are also now those that allow automatic reading and telemetric submission to a central location (Marais, Malekian, Ye, & Wang, 2016). Though taking different forms, each of these systems reconfigure the relationships between water users, providers and infrastructures.

Benefits of these technologies have been observed. For example, Water ATMs reduce the transmission of waterborne disease and avoid plastic pollution in communities without access to a formal drinking water supply (Sarkar, 2019). They can also address issues of corruption and discontinuity in water supplies, with benefits for both users and providers. In Kenyan informal settlements, Chambers and Evans (2020) found that IoT technologies "smooth out the fluctuations associated with accessing resources" (p.11). Water ATMs contribute to reconfiguring trust between water providers and users, and also increase personal economies. Users of Water ATMs are better able to plan daily activities knowing that water would be accessible when needed. Users also gain assurance that they are paying for the quality and volume of water they expect. As Chambers and Evans note "Prior to IoT installation, the infrastructures [that water users] engaged with were possibly not being provided honestly, it was not a safe product, the price might have been artificially manipulated or they were being offered an inferior product" (Chambers & Evans, 2020, p. 7). In this case Water ATMs are seen to be "honest" devices, ensuring price, volume and quality of supply and protecting domestic consumers and small businesses from corrupt water providers. In addition to being "ultimate" cost-recovery tools for water utilities, prepaid systems remove intermediaries and other administrative costs involved in service provisioning. This may help reduce the cost of water for consumers (Heymans, Eales, & Franceys, 2014; Hope et al., 2011).

Notwithstanding such benefits, however, a growing body of literature raises concerns that prepaid meters and Water ATMs extend the reach state power and erode citizens' rights to, and relationships with water (Anand, 2014; Loftus & Nash, 2016). Prepaid meters become entangled in the neoliberal commodification of water and, by automating the mediation of contracts, aid the transfer of responsibilities for water supply continuity to be passed from water companies and municipalities to households (Harvey, 2005). Embedded market logics, though intended to educate and empower poor communities to participate in modern water systems, introduce metrologies into people's everyday lives that violate basic dignity and human rights to water (von Schnitzler, 2016). Von Schnitzler (2008) describes how prepaid meters force low-income households to scrutinize, rationalize and plan everyday practices to ensure the continuity of water supply for essential needs. Those who can afford to do so can take for granted the water involved in flushing the toilet, brushing teeth, children's play, garden watering, and unplanned events such as providing for guests in the event of a funeral. But, for many, "living prepaid" means that these become luxuries that must be planned for and personally provisioned. Indeed, in Zimbabwe, Reniko and Kolawole (2019) argue that prepaid water systems contradict the Constitution as they discriminate against low-income citizens while wealthy water users benefit from reduced bills as bad debt is reduced.

As a more recent development, Water ATMs have been subject to less research. However, they similarly assign responsibility for water provision to water users, who must ensure their smartcard remains in credit to access water. This transfer of responsibility absolve utilities of many of their obligations in informal settlements. Schmidt (2020) argues that Water ATMs do not alleviate social and spatial inequalities, as public infrastructure remains unevenly accessible. Indeed, Water ATMs can introduce new injustices as their location is politically and socially related to existing, planned, and incomplete infrastructure projects (Schmidt, 2020). Despite their increasing proliferation, Water ATMs remain unevenly accessible and subject to the same distributional injustices as other public infrastructures, particularly for those marginalized through intersecting injustices (i.e., gender, religion, class, and race) (O'Reilly & Dhanju, 2014; Waldron, 2018).

Digitization of water services also has wider impacts that are unevenly experienced within communities. For example, in Lilongwe, Water ATMs design out the requirement for kiosk attendants, a role typically fulfilled by women, thereby reducing opportunities for employment and involvement in water provision (Alda-Vidal, Browne, & Rusca, In press). Using the case of digitally enhanced rural water systems in Africa, Komakech, Kwezi, and Ali (2020) explains that prepaid water technologies create an arena for new entrants, such as telephone providers, technology firms, community organizations and technology developers, to enter water market and, with the use of cloud computing and other IoT technologies, form new relational networks for the transmission of revenue outside of existing water systems. These networks can disrupt traditional water politics; however, they can also exacerbate problems that emerge in a commodified water system. The maintenance of digital infrastructure introduces new overheads in the forms of licensing, data hosting and service fees that are passed on to poor rural households who have few other options for water supply.

Water infrastructure plays roles in both expanding and restricting state power (Meehan, 2014) and digital water infrastructure has potential to either reinforce or reconcile injustices. These examples illustrate how IoT technologies make the political dynamics of water systems more complex and create space for a wider range of actors to become involved in water services. These new constellations of actors have potential to disrupt modern water politics by introducing different conditions for data governance and populations surveillance, for example. However, there remains the possibility that digital water systems preserve and extend the injustices that have emerged within modern water. The insights that are offered in existing empirical research are typically distanced from policy visions of digital water futures, which limits the possibility that emerging technologies can be used to overcome historical injustices. It is therefore appropriate that as IoT technologies become more widespread, water studies continue to question digital water politics, and understand the extent to which digitalization disrupts unjust water management practices.

4 | PLATFORMIZATION AND ENTANGLED EVERYDAY LIVES: COMPLEXITIES IN DIGITAL WATER DEVELOPMENTS

The previous examples illustrate the contested outcomes of digital water for water management and use. In this section, we explore how platformization reconfigures water services, using the example of laundry. At its simplest, platformization is putting water services on a platform—in this case, a digital one, whereby water services (e.g., cleanliness, hygiene) and water-using practices (e.g., laundry) are coordinated via online and mobile applications. In some cases, digital platforms may be used to extend water service networks across geographical areas or to increase access to new consumers. Here we examine the varied experiences of the platformization of laundry services around the world to understand how digital innovations intersect with sociomaterial practices. Platformization refers to the infrastructures, economic processes and frameworks of digital platforms across economies and livelihoods, which reorganize everyday practices (Poell, Nieborg, & van Dijck, 2019). If laundry is taken to refer to as "the [taken for granted yet fundamental] task of getting 'dirty' clothing and other items clean again and ready for use" (Yates & Evans, 2016, p. 101), then the platformization of laundry describes the increasing use of digital platforms to enable laundry to be achieved.

Digital developments in the water sector are a part of wider cultural, political and material developments in society. These provide opportunities for digital innovation and also effect the direction, pace and efficacy of digital innovation. Innovation occurs with assumptions being made about the services that digital technologies will perform in future, and the qualities of user experience that will be exhibited, assumptions that are not always realized.

The apparent successes of laundry platformization are that they enable affordable on-demand washing services that are conveniently accessed; operating either doorstep collection and delivery model, or with collection points in public places, such as transport hubs. However, the assumptions that platform designers make about the (past and future) relationships between transactional users (washers and customers) effect the degree to which laundry platforms are integrated into domestic practices, and the extent to which they outperform existing laundry practices in terms of social and ecological benefit.

On-demand laundry services such as Zipjet and Laundrapp have become established within the UK, tapping into consumer demand for convenient time-saving practices (Laundry & Cleaning Today, 2020). However, outsourcing laundry remains uncommon, and most people undertake laundry within their own home (Pullinger et al., 2013). This has not always been the case and Watson (2015) describes a historical trend in the UK that fluctuates between outsourcing and domestic laundry practices. The most recent decline in outsourcing is associated with the increasing affordability of washing machines, changes in suburban conurbations, surveillance in laundrettes and the reconfiguration of gendered labor as more women entered the professional workforce (Watson, 2015). Laundry platforms address some of these concerns, providing convenient ways of outsourcing laundry and with the use of drivers and drop-off services overcome the spatial and temporal limits of earlier outsourcing models (e.g., high street laundrettes). However, other matters are not addressed, and in the case of surveillance may be increased as laundry apps generate new forms of data related to laundry. Overall, laundry platforms in the UK presently provide an additional, rather than replacement, service to consumers.

Though outsourcing of laundry may be novel in a European setting, this is not the case in India, where outsourcing has been a longstanding part of hygiene culture (Patel, 2015), to the extent that there has been a slower uptake of domestic washing machines compared to other parts of Asia (Evans, Browne, & Gortemaker, 2018). Laundry services are diverse and ever-changing in India, with new service models emerging such as mobile laundry vans and laundry kiosks (Eyring, Johnson, & Nair, 2011). These new service models depend on digital platforms such as "Dhobilite," "Urban Dhobi," "Dhobiwala," which have become highly investible services (D'Cunha, 2017; Ganguly, 2016). Digitalization provides revenue to new business models that increase service quality and address sustainability concerns (Evans et al., 2018; Patel, 2015). In this case, digital platforms enable higher caste and middle-class customers to more easily outsource laundry to Dhobis (Washers), a socially and economically marginalized group at the lower end of the caste ladder (Patel, 2015, and see Khalid, Christensen, Gram-Hanssen, & Friis, 2019 for a similar account of platformization in Pakistan). Digital platforms aid the expansion of laundry service demand, while at the same time mirroring established class and caste-based hierarchies. There are also uneven gender politics at play, with women often still responsible for laundry within domestic labor settings and outsourced laundry services (Jack, Anantharaman, & Browne, 2020). Digital platforms have become a part of the evolving cultural history of laundry in India; however, the extent to which they alter uneven hygiene cultures and practices remains to be seen.

Different sociotechnical conditions in Kampala have seen digital laundry service models struggle to stabilize. In 2018, Yoza, a subscription service that connects people with laundry to washers in their local area ceased trading after experiencing difficulties recruiting and retaining washers (Kamanzi, 2018a). In this instance an acknowledged technology divide between customers and washers was not overcome (Kamanzi, 2018b). Subscribed washers reported that patronage increased from one or two customers a week to 10–15 (Kamanzi, 2018b), suggesting that the platform enabled washing to become a more viable source of household income (Sarpong, 2015). However, uneven distribution of smartphone ownership meant that while customers could connect to the service, washers were less likely to reciprocate (Kamanzi, 2018b). The platform evolved to provide washer's contact details to customers as a means of increasing connectivity; however, ultimately this model rendered the platform redundant. This example illustrates that in spite of demand for laundry services, existing technology divides are not inherently addressed by digital innovations and impact on their diffusion.

Common digital water imaginaries focus on conspicuous and purposeful technological developments, whereas the differentiated experiences of laundry platformization provide insight into the more mundane digitalization of society. These mundane transformations matter to the everyday politics of water—the almost invisible processes that shape relationships between users, technologies and water systems (Fam et al., 2015; Sofoulis, 2005). The UK experience illustrates the importance of interactions between emerging platforms and existing social practices. In this case, on-demand laundry works because the service model integrates with existing routines, such as commuting, and enables the navigation of time-scarce society (Southerton, 2003). In contrast, the Ugandan experience illustrates that platforms themselves are insufficient to overcome a well understood digital divide. Here the success of platformization was limited as though demand for washing existed, washers had limited access to smartphones and it was therefore difficult to connect users to washers. Lastly, the Indian case illustrates how platform service models build on existing transactional relations and infrastructures, rather than establishing new ones and in doing so risks reproducing and deepening social hierarchies based on class, caste and gender.

Laundry services provide just one illustration of platformization and many aspects of water are finding their way onto digital platforms, from meter reading (Suresh, Muthukumar, & Chandapillai, 2017) to storm water management (Mullapudi, Bartos, Wong, & Kerkez, 2018). Each of these developments have their own implications for water politics and practice, but one thing they have in common is that platforms are designed with anticipation of future hydrosocial relations that are not necessarily borne out in practice. As part of the ongoing evolution of water systems, digital innovations are entrenched in social, cultural, political and material developments. Digital innovation could have capacity to alter the trajectory of water service systems, however, could also serve to further deepen relationships that are neither sustainable or just. Social science research provides lenses through which to observe the complex dimensions of water service systems, and with it the capacity to generate more informed assumptions (Sofoulis, 2015). It is therefore important that we continue to question how insights from a diverse array of literatures can inform visions of digital water and direct change toward more inclusive sustainable futures.

5 | REGULATING DIGITAL WATER: UNFOLDING PROTECTIONS FOR CRITICAL INFRASTRUCTURES

As digital technologies become embedded throughout society, the technical standards and regulations that shape the water industry are also shifting. The nature of regulation is contingent on the interplay of technology, expertise and politics (Shove & Trentmann, 2018) and, in turn, regulations have implications for the direction of innovation. While investigating digital water regulations, it is pertinent to ask *whom and what* regulations are intended to protect, for example, water, residents, states' interests or suppliers' reputation? Furthermore, who decides what is protected and what are the acceptable risks? These questions can be explored by looking at the relationships, narratives and expertise that shape governance (Jasanoff, 2004). In this section, we focus on the coevolution of digital water technologies and regulation. In the first instance, we turn to the literature on critical infrastructure to understand how politics and expertise shape regulation. We then discuss how digitalization in the water sector is being shaped by regulation, focusing on two European Union directives: General Data Protection Regulations (GDPR) (European Parliament, 2016a) and Network and Information Systems Security (NIS) (European Parliament, 2016b).

While analyzing coproduction of digital regulations, there is value in seeking to understand the politics and expertise of practitioners involved in the water sector. Practitioners are diverse, and becoming increasingly more so. For example, this term would include plant operators, engineers, water resource managers, planners and regulatory bodies. Practitioners' have different backgrounds (e.g., in the public sector, private sector, academic or other) and their expertise has arisen in different disciplines, with different epistemic norms and praxis. Recognizing the plurality of expertise involved in water governance, helps to reveal how the complexity of hydrosocial systems is made sense of and managed, and how different interests are negotiated (Li, 2007).

Expertise is often viewed as apolitical, such that decisions made in the water sector could be understood as evidence-based and therefore value-free. However, scholars in critical infrastructure studies, among others, have consistently demonstrated the value-laden and relational qualities of expertise, which shape judgments about what forms of evidence are to be incorporated into action (Nowotny, 2003; Slayton & Clark-Ginsberg, 2018). From this perspective, seemingly technical decisions are guided by a range of intrinsic motivations (e.g., cost saving, convenience, compliance or ensuring water quality). In contrast, when matters of water supply and demand are seen as purely technical issues, there remains limited scope to question, for example, what standards of water security should be upheld, at what cost, and whose norms of cleanliness or convenience should be incorporated into action (Fam et al., 2015).

Digital transformation introduces new equipment and expertise to the water sector (Wallis & Johnson, 2020). Water supply and sewerage infrastructure have in the past been disconnected from the public internet and operated on legacy equipment; established site-specific monitors and controls that employ nonencrypted communications protocols. Digital water sees water infrastructure connected to the Industrial Internet of Things (IIoT), a network of sensors that communicate directly with each other to automate control decisions. The IIoT is a material intervention in water infrastructure that introduces new operational technologies to the water system. With it, new actors become important (e.g., IT start-ups, hardware and software manufacturers, new regulatory bodies), with expertise and politics that extend those that already exist within the water sector.

Different regulations also become applicable as digitalization unfolds. GDPR and NIS are European-scale directives that are intended to ensure data protection and cybersecurity. These directives become increasingly relevant as digital developments unfold in the water sector. While a range of benefits are expected to emerge from their implementation, each of these directives has implications for the framing of digital water regulation, as well what digital transformation should be directed to achieve, and what forms of expertise are valued. A number of possible narratives are unfolding around the protection of digital water systems (Michalec, van der Linden, Milyaeva, & Rashid, 2020). Cyber security and privacy can be framed as a technical issue, focused on the maintenance of physical assets and an arena for technical expertise. Alternatively, cyber security and privacy can be viewed in the context of "securitization," and become an area for state-endorsed spending on surveillance and control (Carr & Tanczer, 2018; Lavorgna & Sergi, 2016). Another alternative is that cyber security and privacy regulation are as a means to ensure that digital infrastructure protects public services, such as water supply quality and continuity, keeping them within the realm of water practitioners (Michalec et al., 2020). Finally, a fourth possible framing is that NIS and GDPR are implemented in ways that increase the transactional value of water systems, and economic expertise becomes more relevant (Loftus, March, & Purcell, 2019; Sadowski, 2019).

As these directives are in the early stages of implementation, it is worthwhile to consider that there are cobenefits and trade-offs to each position, and different implications for the expertise that become established in digital water systems (Espinosa Apraez & Lavrijssen, 2019). Furthermore, their implementation is not straightforward. Carr (2016) illustrate how the mismatch in expectations between public and private parties leaves ambiguities in the roles, responsibility and authority involved in implementing cybersecurity strategies. Michalec et al. (2020) observe tensions arising between different cyber security communities of practice, particularly Operational Technology engineers, IT specialists and digital products vendors. Similarly, Slayton and Clark-Ginsberg (2018) show how implementation requires the negotiation of different epistemologies and praxes, negotiations that are contingent on historical events and relationships and continuously evolving. These nuances adds further complexity to water governance, and water scholars might valuably contribute to interpreting the relationships between security, privacy and digitization for the water industry.

Maintaining attention on the interdependencies between technology, regulation and expertise will better enable us to understand the purpose and direction of digital water developments. The cases presented within this article demonstrate some of the technologies, processes and actors becoming involved in the water sector, and there are many others. It is interesting to question what will be the role of these actors within already complex multitiered water governance systems, and to attend to how their expertise and interests shapes the onward trajectory of water policy. There are already concerns that there are gaps and insufficiencies emerging within the disconnected web of policies, regulations and planning frameworks relevant to water systems (Robins, Burt, Bracken, Boardman, & Thompson, 2017; Sharmina et al., 2016), and limited assurance that regulations becoming relevant with the advance of digitalization will address these. Indeed, one possibility is that these introduce additional conflicting interests and further disintegration that makes it more complicated to ensure whole-system decision making. It is therefore important to ask how additional regulations can help to address social and ecological problems. Given additional pressures to professionalize the field of cyber security (e.g., introduce university courses, certifications and career paths), it is also valuable to question what training is provided so that the social and ecological problems that face water systems are more widely understood (Reece & Stahl, 2014).

6 | OPENSOURCE DATA AND SENSING: ENABLING PARTICIPATION IN WATER GOVERNANCE

The previous sections have examined some of the more negative sociopolitical effects of digital water transformation. It is also important to attend to the positive outcomes that digital transformation could offer. In this section, we examine how digital technologies widen civic participation in water governance. Njue et al. (2019) highlight the important role that citizen science can play in gathering hydrological data to improve water planning and management. The uptake of digital methods and resources valuably extend citizen data collection, improving the quality, timeline and duration of datasets (Njue et al., 2019). However, we should also be interested in how digital technologies enable participatory decision making. Outside of water studies, digital scholars have identified cases where digital technologies enable progressive digital politics (Crawford, 2016). “Civic-hacking,” where citizens collaborate to develop solutions to local problems, and digital cooperatives and protests (e.g., “cloud protests” [Ettlinger, 2018]) involve the use of digital innovations such as open access data and code, applications and low-cost sensing technologies to develop inclusive solutions to societal problems (Gabrys & Pritchard, 2018; Johns, 2016). These literatures show how digital technologies can enable civic participation in decisions making. Here, we examine the implications of this scholarship for thinking about a more participatory hydrosocial contract.

In the domain of water, D'Ignazio and Zuckerman find that citizen sensing “holds promise for a new informational landscape for citizens to monitor their world and mobilize their communities when threatened” (D'Ignazio & Zuckerman, 2017, p. 143). Examples include Coqui, a device that measures conductivity of water (a basic measure of water quality) and CATTfish, a fish-shaped sensor placed in the toilet that senses when a well has been compromised by fracking. Each case illustrates ways that inexpensive sensors and open data empower citizens to further understand their local environment. They also show how these resources allow citizens to hold institutions to account, providing equipment and skills to examine issues of concern (D'Ignazio & Zuckerman, 2017). Another example, provided by Rey-Mazón et al. (2018), is the RIFFLE, a low-cost open source water monitor which is used to document water quality upstream and downstream of a potential polluter. The RIFFLE offers a means for communities in mining regions of Colombia to identify abrupt changes in water conductivity, providing a decentralized environmental monitoring system in a situation where surveillance is otherwise minimal and highly politicized. In turn this data enables communities to visually represent the impacts of mining on the local environment, and hold mining companies to account.

Overall, digital water innovations could provide opportunities to unsettle the concentration of knowledge in scientific and industrial communities that has occurred within a modern water contract. Affordable sensing technologies, open data, and increased connectivity that comes with digital information systems enables a more collective mode of water governance than has previously been possible. Furthermore, with digital technologies providing citizens and communities with data to hold institutions to account (D'Ignazio & Zuckerman, 2017), there is potential for digital water transformations to further the coproduction of water services (Pritchard & Gabrys, 2016). Opensource data and sensing equipment can help citizens to represent longstanding matters of concern in visual ways that can help mobilize just transitions (Chilvers & Longhurst, 2016; Elwood & Leszczynski, 2018). However, digital tools themselves create few opportunities for higher modes of learning (Mukhtarov, Dieperink, & Driessen, 2018), and do not replace deliberative processes (Beer, 2017). There is therefore a need for the water sector to establish deliberative processes that support and include citizen sensing. With data as the new “currency of power” (D'Ignazio in Thylstrup & Veel, 2017, p. 68), scholars, practitioners and publics could further explore how digital innovations could enable productive resistance to address inequalities within the water system.

7 | DISCUSSION AND CONCLUSION: RESOCIALIZING DIGITAL WATER TRANSFORMATIONS

This article set out to reinfuse digital water imaginaries with social and political sensitivities from an interdisciplinary body of social science scholarship. Water management has undergone a paradigm shift in recent years, such that governance and sociocultural dynamics have become matters of concern. However, when it comes to digital water transformation there remains a chasm between industry visions and scholarship that illuminates the complexities, tensions and unintended consequences. In developing five case studies of digital developments, we further an understanding of digital water futures, and highlight positive and negative sociopolitical impacts. Further work is still required, within academia and beyond, to develop a more socially and politically informed account of digital transformation in the water sector. In this section, we discuss questions and approaches that might inform this research agenda (summarized in Figure 1).

The case studies demonstrate how critical research—that which "foregrounds the contingency of knowledge, social structures, and relations” (Machen, 2019, p. 329)—can be used to expand technology-oriented visions and reflect on the sociopolitical developments with which digital innovations are entwined. By using these literatures to analyze digital

FIGURE 1 A roadmap for resocializing digital water research

An incomplete list of further research questions:
How do digital developments unsettle (or further deepen) modern water politics?
How do modern water politics frame sociotechnical imaginaries of digital water transformation?
What properties of water systems are represented, and what remains obscured?
How can representation of water systems be improved with diverse datasets, including qualitative, informal, and context-specific data?
What are the politics of digital water systems?
How can deliberative processes aid the meaningful integration of these datasets, and/or enable coproductive governance?
Who and what is excluded or marginalized from digital water services and governance?
How do digital water development overcome (or reaffirm) injustices and inequalities?
What tensions and contestations are arising in digital water transformations?
What are the implications of digital technologies for responsibility, accountability, and control?
What kinds of expertise are included in decisions about water systems?
What (and whose) interests are regulations applied to digital water systems are designed to serve?
How can additional regulations help to address social and ecological problems?
Who decides what are the acceptable risks of digital transformation?
How can digital technologies mobilize productive resistance and participation to shape water governance?

Recommended approaches
Commitment to knowledge and methodological pluralism
Funding for transdisciplinary collaborations
Platforms for interdisciplinary exchange and learning
A culture that recognizes and challenges assumptions
Meaningful involvement of citizens and other stakeholders
Platforms for experimentation and action research

developments, we can alert those involved in the design and governance of digital water to potential exclusions and foreclosures, and accentuate possibilities for empowering (marginalized) water users. Many questions have been raised within this article; regarding how to enhance the representation and understanding of water systems; how to recognize and potentially overcome inequalities and injustices; how to question epistemic norms and practices; and how digital technologies might mobilize a more inclusive model of water management. Investigating these questions pushes the boundaries of current discourse, which relies on dominant disciplines such as engineering and management. Future studies should aim to diversify imaginaries of digital water. Participation, coproduction, and knowledge and methodological pluralism are key aspects of this diversification, as digital transformation creates new focal points and methods for collaboration. These questions and approaches are summarized in Figure 1 and discussed below, providing a roadmap for future enquiry.

Digital technologies present new possibilities for individuals and communities to shape water research, policy and management. Privatization and financialization are characteristic of modern water and have impacted water service systems around the world. These processes cast individuals and communities as customers, and limit opportunity for participation in decision-making (Page & Bakker, 2005). Through the case studies in this article, we have shown digital developments present opportunities to resist this casting, and introduce possibilities for water users to be active comanagers of water systems. They also offer means of increasing inclusivity; enabling the knowledge and experience of different collectives (including those of marginalized gendered, ethnic, religious, socioeconomic communities) to inform water management. Indeed, there is no singular water system, and digital technologies provide ways to examine local biophysical, social and political conditions as well as diversities within geographic locales. But there is a need to create space for these understandings to guide water governance.

Achieving more participatory digital water governance requires changes in governance and institutional practices. Meaningful civic participation begins with the cocreation of visions to inform the trajectory of digital developments. The visions of digital water pervasive throughout the sector are normative; embedding assumptions about the needs and aspirations of citizens and society. These assumptions are limited and informed by the perspectives and experiences of their curators (Jasanoff, 2017; Sofoulis, 2014). Therefore, it is vital that water governance establish ways for individuals and communities to coproduce assumptions, and processes to include diverse needs and aspirations (Vanolo, 2016). Part of this processes is to recognize informal and indirect modes of participation (Page & Bakker, 2005), particularly given the new possibilities that citizen sensing affords (Pritchard & Gabrys, 2016). A key aspect of innovation is that it opens up ways for citizens to participate in setting agendas for the future of water systems (Stilgoe, Owen, & Macnaghten, 2013). The challenge, in a digital future, is to recognize many alternative forms of data, evidence and participation and meaningfully incorporate these in decision making and management processes.

Finally, to enable robust interdisciplinary advances in digital water studies, there is need to address historical disparities in disciplinary uptake. Parity between disciplines requires that interpretive, qualitative and context-specific knowledge are valued and respected to cultivate more socially and culturally intelligent representations of water systems (Sofoulis, 2015). We have discussed how interdisciplinary approaches could enable Big Data, artificial intelligence and machine learning techniques to more fully represent water systems, and how participatory digital methods could be used to generate grounded data and analytical sensitivities to address historical obfuscations. These developments could improve modeling, prediction and planning in water systems (Hoolohan, McLachlan, & Larkin, 2019; Sharmina et al., 2019; Ward et al., 2019), but require a pluralistic research environment that addresses the underrepresentation of the social sciences in evidence-based policy and planning. A pluralistic research environment is sensitive to differences in epistemologies and praxes in research communities and supportive of mutual social learning (Pahl-wostl et al., 2007). This is not a new proposition (e.g., see Fam & Sofoulis, 2016; Pahl-Wostl, Lebel, Knieper, & Nikitina, 2012; Sharp et al., 2011), however, has not yet been resolved. The multiple uncertainties and potential places to replicate inequalities in digital transformation, accentuate the value of interdisciplinary collaborations.

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Claire Hoolohan: Conceptualization; investigation; methodology; writing-original draft; writing-review and editing. **Godfred Amankwaa:** Investigation; writing-original draft; writing-review and editing. **Alison Browne:** Investigation; writing-original draft; writing-review and editing. **Adrian Clear:** Investigation; writing-original draft; writing-review and editing. **Kirsty Holstead:** Investigation; writing-original draft; writing-review and editing. **Ruth Machen:** Investigation; writing-original draft; writing-review and editing. **Ola Michalec:** Investigation; writing-original draft; writing-review and editing. **Sarah Ward:** Investigation; writing-original draft; writing-review and editing.

CONFLICT OF INTEREST

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